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Ministry of the ENVIRONMENT

The Effects of Influent Alum Injection on the Effluent from Continuous Discharge Lagoons

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THE EFFECTS OF INFLUENT ALUM INJECTION ON THE EFFLUENT FROM CONTINUOUS DISCHARGE LAGOONS

By:

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Research Branch

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ABSTRACT

In order to investigate the reduction of phosphorus concentration in the effluents from continuous discharge waste stabilization ponds, alum has been injected directly into the raw sewage influent to the east cell of the Shelburne lagoon system.

At a dose rate of 170 mg/l (Al:P ratio of 1.05:1), 80 percent of the influent phosphorus was retained in the test cell over the period of the study. Suspended solids and BOD removal was better than in the control cell. The addition of alum did not appear to upset the natural biological processes of the pond.

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1. INTRODUCTION

The increased emphasis on reducing the nutrient discharge, primarily phosphorus and nitrogen, from sewage treatment plants has prompted various investigations into controlling the effluent concentrations of nutrients from waste stabilization ponds (WSP).

Soluble phosphorus may be retained in a waste stabilization pond naturally by algal metabolism and sedimentation or through precipitation as calcium phosphate. Precipitation of calcium phosphate occurs when the pH of the pond contents is raised due to carbon dioxide utilization by the algae. These natural mechanisms have not been found adequate for controlling the amount of phosphorus discharged in pond effluents. (1)

Alum, ferric salts or lime (2) may be mixed with raw sewage, flocculated and clarified to remove much of the 5-day Biochemical Oxygen Demand (BOD), suspended solids (SS) and phosphorus as part of the resultant sludge. The clarified supernatant would then overflow to the WSP for further BOD and SS reduction and pH neutralization. This method would involve considerable modification of the influent structure including the construction of flocculation and sludge storage tanks; a means of sludge disposal would also be necessary.

Laboratory investigations conducted by the Research Branch, Ministry of the Environment indicated that direct injection of chemical coagulants into the raw sewage influent line can be an effective method of enhancing the reduction of total phosphorus in the effluent from a waste stabilization pond. A system of this type was installed at the Shelburne WSP.

Ontario

✓Copy of this approval made for Mr. A. J. Harris -6/7/73.

Ministry of the Environment

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MEMORANDUM July 5, 1973.

TO: The Honourable J. A. C. Auld,
Minister of the Environment.

FROM: Fred A. Voege, Executive Director,
Laboratory & Research Division.

RE: REPORT ON, THE EFFECTS OF INFLUENT ALUM INJECTION ON THE EFFLUENT FROM CONTINUOUS DISCHARGE LAGOONS.

Attached is a report on the initial study conducted by the Research Branch on the effect of adding chemicals, in this case alum, to the raw sewage being fed to a continuous discharge lagoon.

The analytical results of the effluent of the treated cell indicate that, with a relatively small expenditure of funds for equipment and chemicals, it is possible by adding alum by this method to increase the retention of the phosphorus received in the raw sewage from an average of 57.6% to an average of 79.9%. Further work is underway as part of the Canada/Ontario Research Agreement using increased dosages of chemicals and other chemicals such as ferric chloride and lime.

With your approval, this report will be distributed in the usual manner to municipalities, consultants, and others that would be expected to make good use of the information it contains.

Fred A. Voege

FAV:bm
Attachment.

cc: Messrs. D. S. Caverly,
A. J. Harris.

July 7/73 Approved

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ORIGINAL SIGNED BY
FRED A. VOEGE

FAV:bm
Attachment.

cc: Messrs. D. S. Caverly,
A. J. Harris. ✓

2. GENERAL

The village of Shelburne (population 1500) is located at the junction of Highways 10 and 89 at the geographic centre of Dufferin County, Ontario. The village functions as a residential and farming community centre with no industry except for one feedmill.

The mean winter temperature of the Shelburne area is $20^{\circ}F$ ($-7^{\circ}C$) and the mean summer temperature is $65^{\circ}F$ ($18^{\circ}C$). There are about 130 frost-free days/year. Mean annual rainfall is 27 in. (69 cm.) and snowfall is 100 in. (254 cm.).

Sewage treatment is provided by a 13.2 acre (5.32 hectare) continuous discharge waste stabilization pond consisting of two 6.6 ac (2.66 ha.) cells operated in parallel. Average flow to the WSP during the period covered by this report was 0.184 MIGD (837 m^3 per day) with a 5-day BOD loading of 22.7 lbs./ac/day (25.5 kg/ha/day). Average total phosphorus concentration in the influent was 12.2 milligrams per litre (mg/l).

Alum was injected into the influent of the east cell; the west effluent was monitored as a control to compare differences in treatment efficiency.

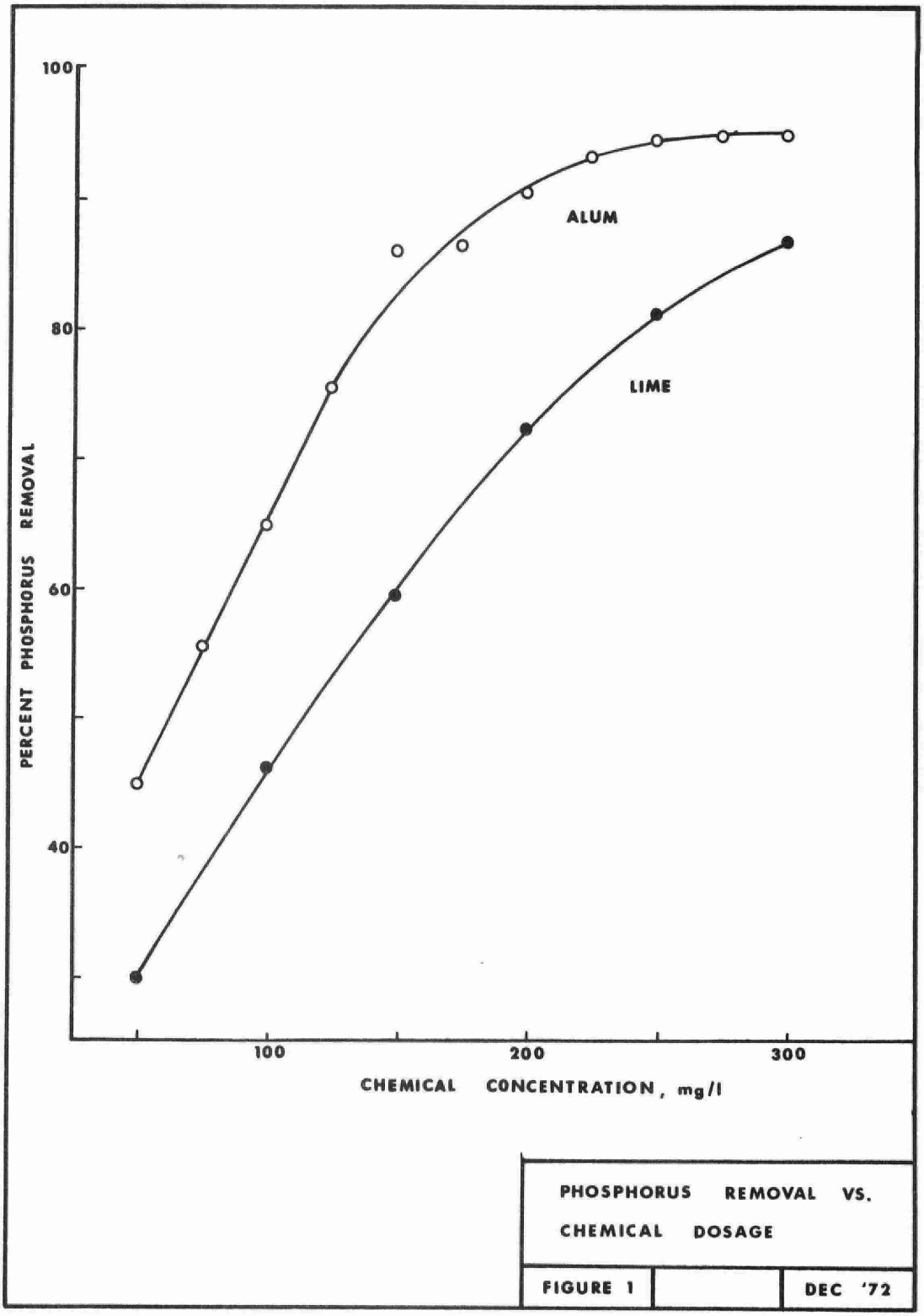
3. PRELIMINARY

3.1 Jar Tests

A number of grab and 24-hour composite samples were obtained from the raw sewage wet well at Shelburne for a period of two months prior to chemical injection. These samples were jar-tested according to a standard procedure (5 minutes fast mix, 15 slow, 40 quiescent) with alum ($Al_2(SO_4)_3.14\ H_2O$) and with lime ($Ca(OH)_2$) at concentrations ranging from 50 to 300 mg/l. The supernatant was decanted and submitted to the laboratory for total and soluble phosphorus determinations.

The average percent total phosphorus removals using alum and lime were calculated and plotted as a function of chemical concentration (Fig. 1). For 80 percent phosphorus removal, an Al:P ratio of 1.05:1 was required. For average field conditions and the same Al:P ratio, it was calculated that approximately 170 milligrams alum per litre raw sewage were necessary to remove 80 percent of the influent phosphorus.

The decision to use alum in this pilot study was based on the higher phosphorus removals per unit dosage obtainable as compared to lime.



PHOSPHORUS REMOVAL VS. CHEMICAL DOSAGE

FIGURE 1 | | DEC '72

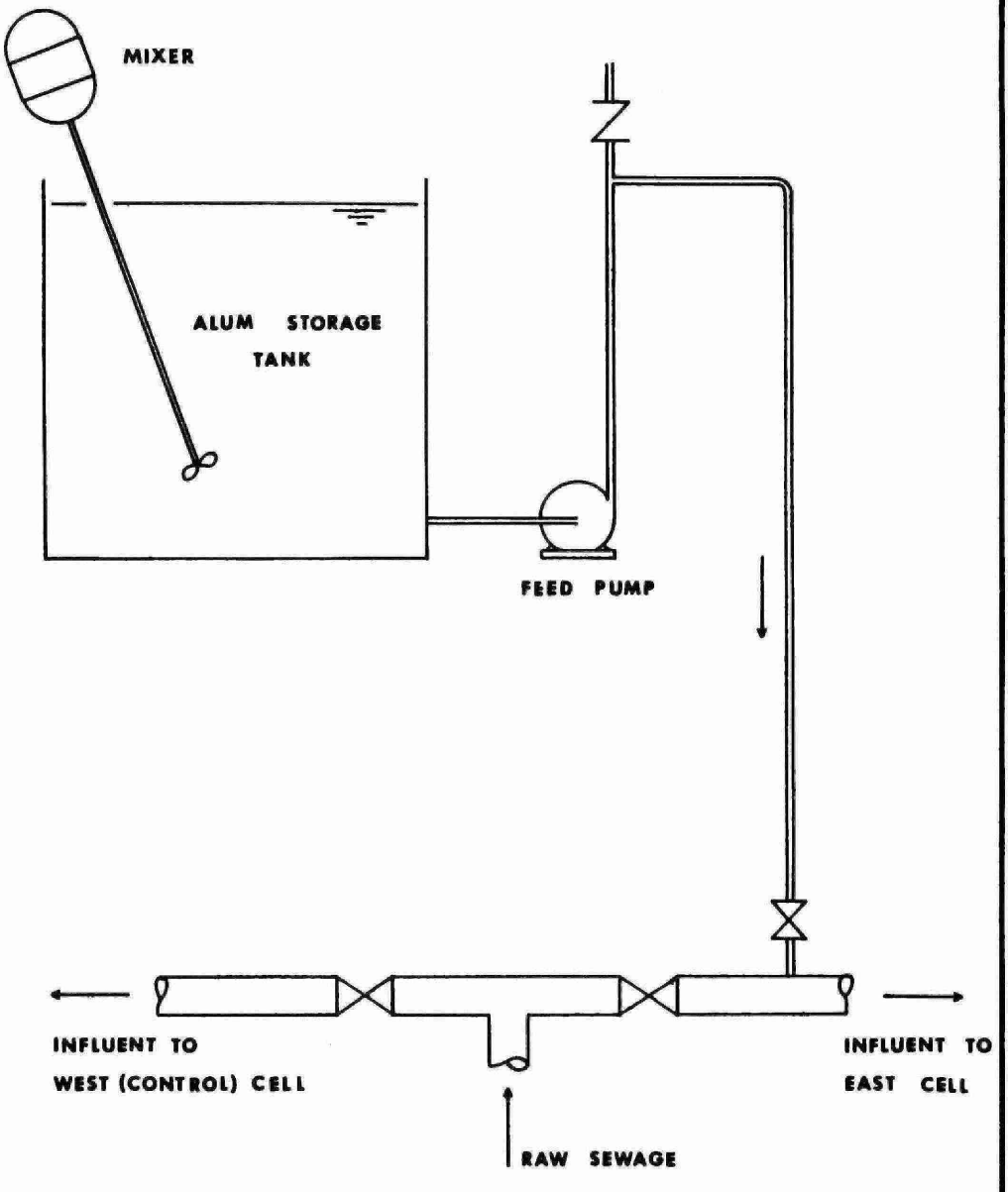
3.2 Field Installation

An injection point was tapped into the pipe leading from the forcemain junction to the centre of the east cell of the Shelburne ponds. Two interconnected 300 gallon (1.36 m^3) polyethylene tanks were housed in an insulated building for alum storage. An electric diaphragm pump connected to a relay and timer which operated off the lower float switch in the raw sewage wet well was used to inject alum into the raw influent (Fig. 2).

The chemical feed solution was prepared by adding 500 pounds of alum to sufficient water to produce 100 gallons of slurry. This mixture was stirred continuously to keep undissolved alum in suspension.

A level recorder and V-notch weir were installed in the effluent box of the east cell to determine outflow rates.

Injection of alum at a concentration of 170 mg/l into the influent to the east cell commenced on June 17, 1971 and continued to September 30, 1972, a period of approximately 6 times the theoretical retention period.



ALUM INJECTION SYSTEM

FIGURE 2 | | DEC '72

4. SAMPLING PROGRAM

A regular sampling program was started at the commencement of chemical treatment. This consisted of weekly grab samples of the east (treated) and west (control) cell effluents and raw sewage. Samples were analyzed for the following parameters according to Standard Methods (3):

5-day Biochemical Oxygen Demand (BOD)

Suspended Solids (SS)

pH

Total and Ortho-(Soluble) Phosphorus (P_t and P_s)

Nitrogen; Free Ammonia (NH_3), Total Kjeldahl (Kjel), Nitrite (NO_2), Nitrate (NO_3)

Alkalinity (alk)

Hardness

Chlorophyll a, b

Total and Fecal Coliforms

A summary of raw sewage and effluent analyses is given in Appendix II.

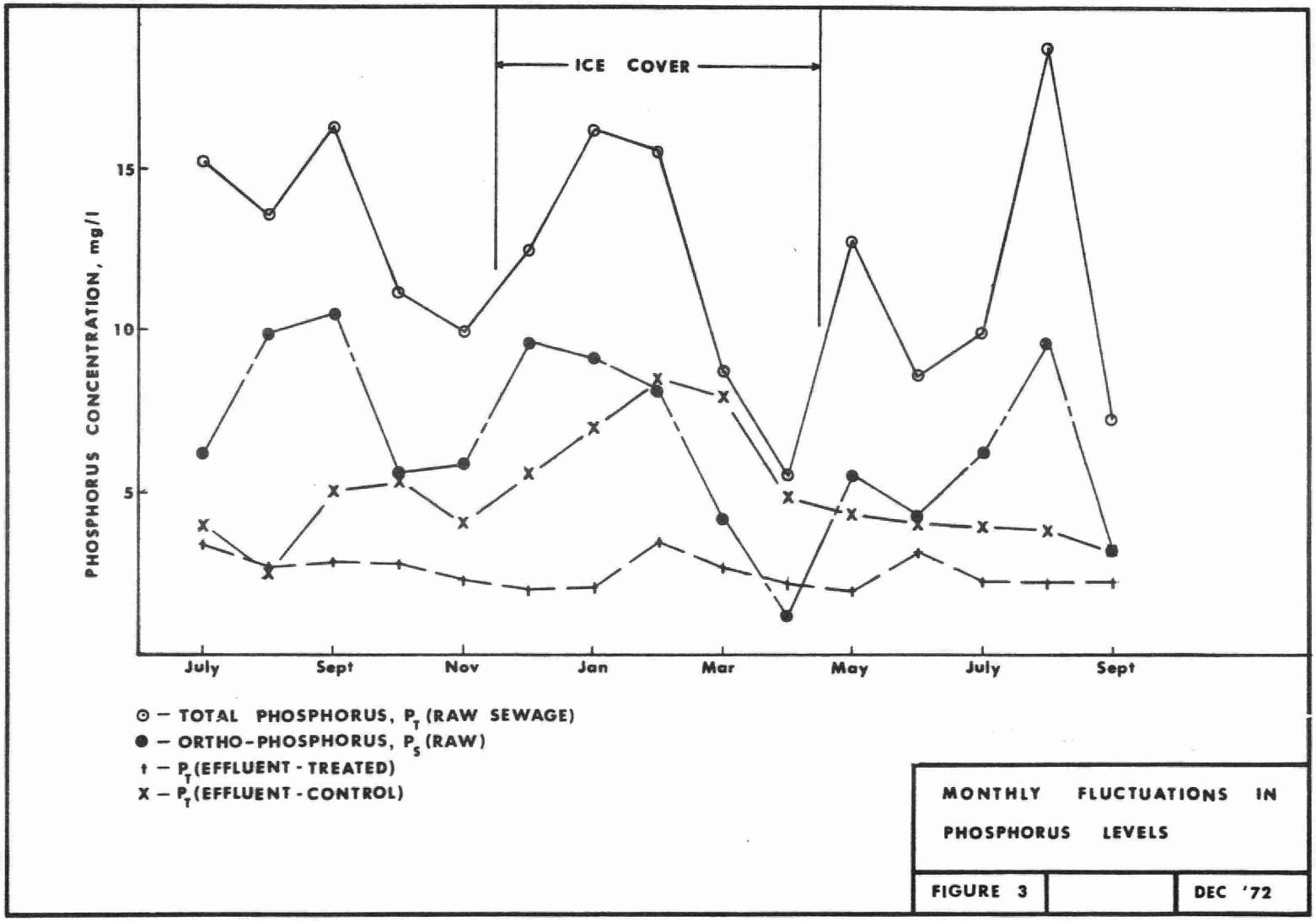
5. RESULTS

5.1 Phosphorus

The monthly variations of total phosphorus concentrations in the effluents from the treated and control cells and the raw influent total and ortho-phosphorus values are shown in Fig. 3. Using these data, monthly totalizer values from the sewage pumps, and outflow rates measured by the level recorder, a mass balance of the total influent and effluent phosphorus for the two cells was calculated (Appendix I). From this it was determined that of the total phosphorus in the influent 79.9 percent was retained in the treated cell and 57.6 percent in the control.

Phosphorus levels in both effluents were generally much lower than the total influent values during ice-free months. From February to April, oxygen depletion occurred in both cells and it appears that phosphorus release from the bottom sediments of the control cell resulted in an effluent with a higher ortho-phosphorus content than that of the influent (Appendix II). This effect was not evident in the treated cell and is due to the stability of the aluminum - phosphorus compound.

Average total phosphorus concentrations, for the period of the study, were: raw influent -12.2 mg/l; control effluent - 4.9 mg/l; treated effluent - 2.55 mg/l.



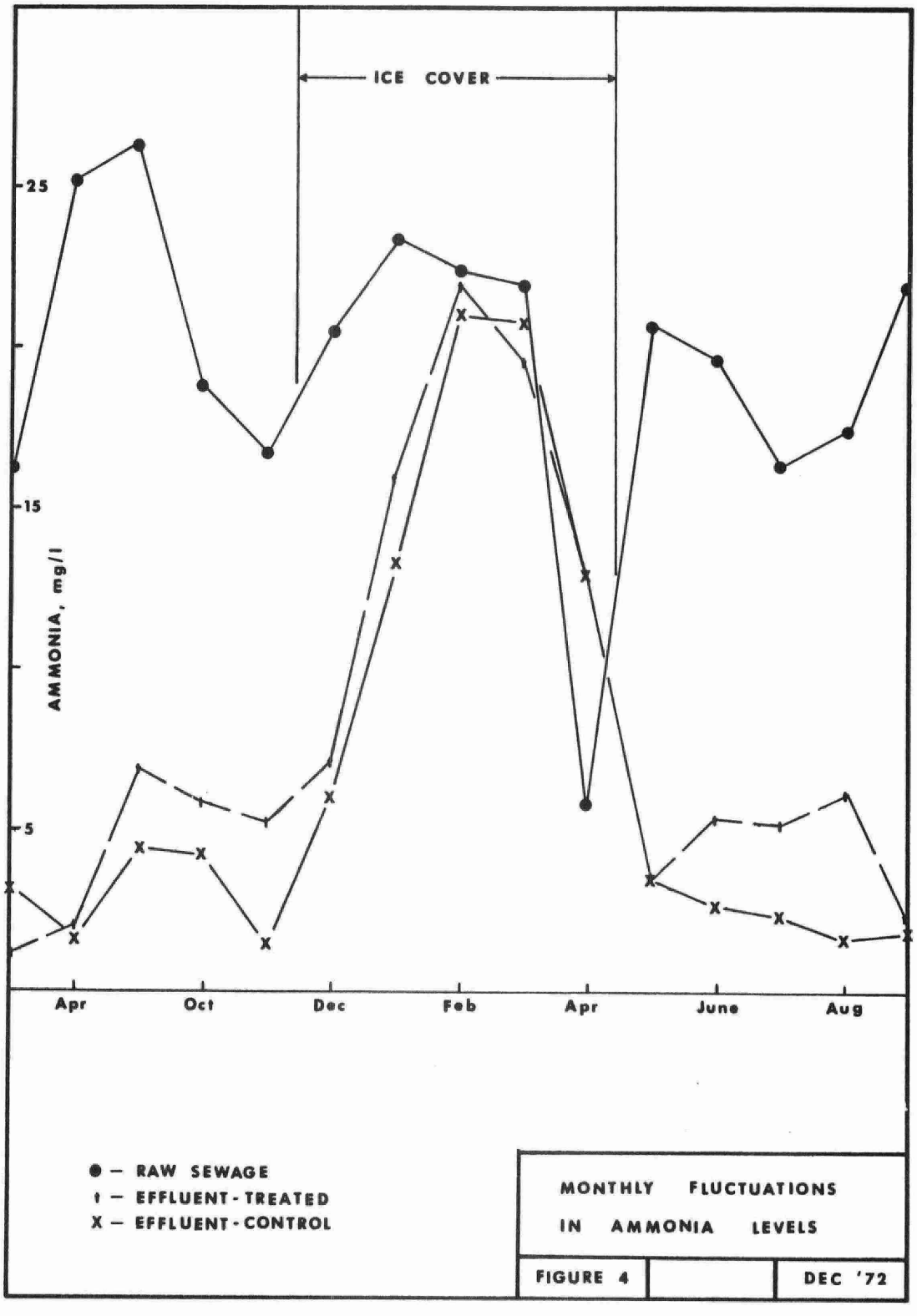
MONTHLY FLUCTUATIONS IN PHOSPHORUS LEVELS

FIGURE 3 | DEC '72

5.2 Nitrogen

Algae in a waste stabilization pond, metabolize free ammonia (NH_3) in the raw sewage, and are thus responsible for a large percentage of the organic nitrogen (arithmetic difference between total Kjeldahl and free ammonia) in pond effluents during the summer. As a result of reduced algal activity during the winter, the difference between influent and effluent ammonia levels decreases.

The monthly averages of free ammonia in the influent and effluents from the control and treated cells are shown in Fig. 4. Ammonia reduction was generally better in the control cell, particularly during the summer months. As the ice thickness increased from mid-November to a maximum in February, the effluent ammonia levels approached those of the influent and exceeded the influent values in April, during ice breakup. The organic nitrogen levels were similar in both effluents; the averages for the summers of 1971 and 1972 were 7.9 mg/l and 8.8 mg/l respectively and the average for the 71/72 winter was 5.1 mg/l.



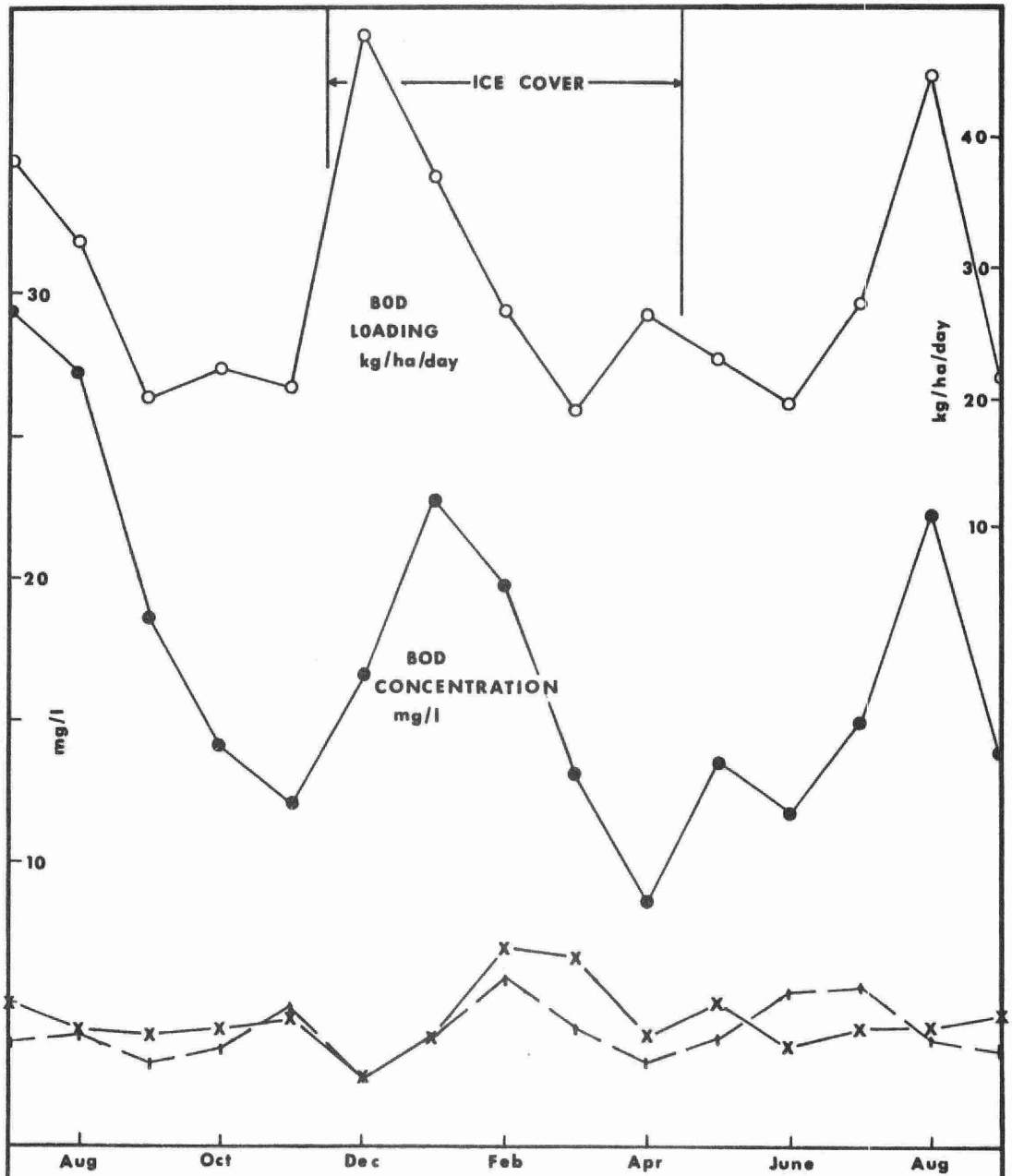
MONTHLY FLUCTUATIONS IN AMMONIA LEVELS

FIGURE 4 | DEC '72

5.3 BOD and Suspended Solids

The average BOD loading to the two cells for this study was 22.7 lbs./ac/day (25.5 kg/ha/day). Effluent BOD varied directly with the influent loading after a one to two month lag period during the winter (ice cover) months (Fig. 5). Variations in BOD were not as predictable during the ice-free months, being influenced more by the gross effects of solar radiation, wind and temperature on algal photosynthesis and bacterial metabolism.

Suspended solids concentrations were relatively low (14 to 38 mg/l) during the period of thick ice cover (Appendix II). After spring break-up of the ice cover (mid-April), suspended matter in the effluents increased significantly as a result of rapid algae growth. This effect was particularly evident in August, 1971 when heavy rainfall dispersed a blue-green algae matt on the surface of the treated cell resulting in high effluent suspended solids from that cell. Suspended solids levels were, on the average, lower in the effluent from the treated cell.



MONTHLY FLUCTUATIONS IN BOD LOADINGS AND CONCENTRATIONS

FIGURE 5 | | DEC '72

5.4 Alkalinity and pH

Algae utilize carbon dioxide during photosynthesis resulting in lowered alkalinity and increased pH levels; therefore a measure of these parameters is an indication of algae activity. The presence of ice cover on a lagoon during winter limits the availability of photosynthetic oxygen produced by algae, to aerobic bacteria and eventually results in an anaerobic environment. This is characterized by an increase in alkalinity and reduction in pH.

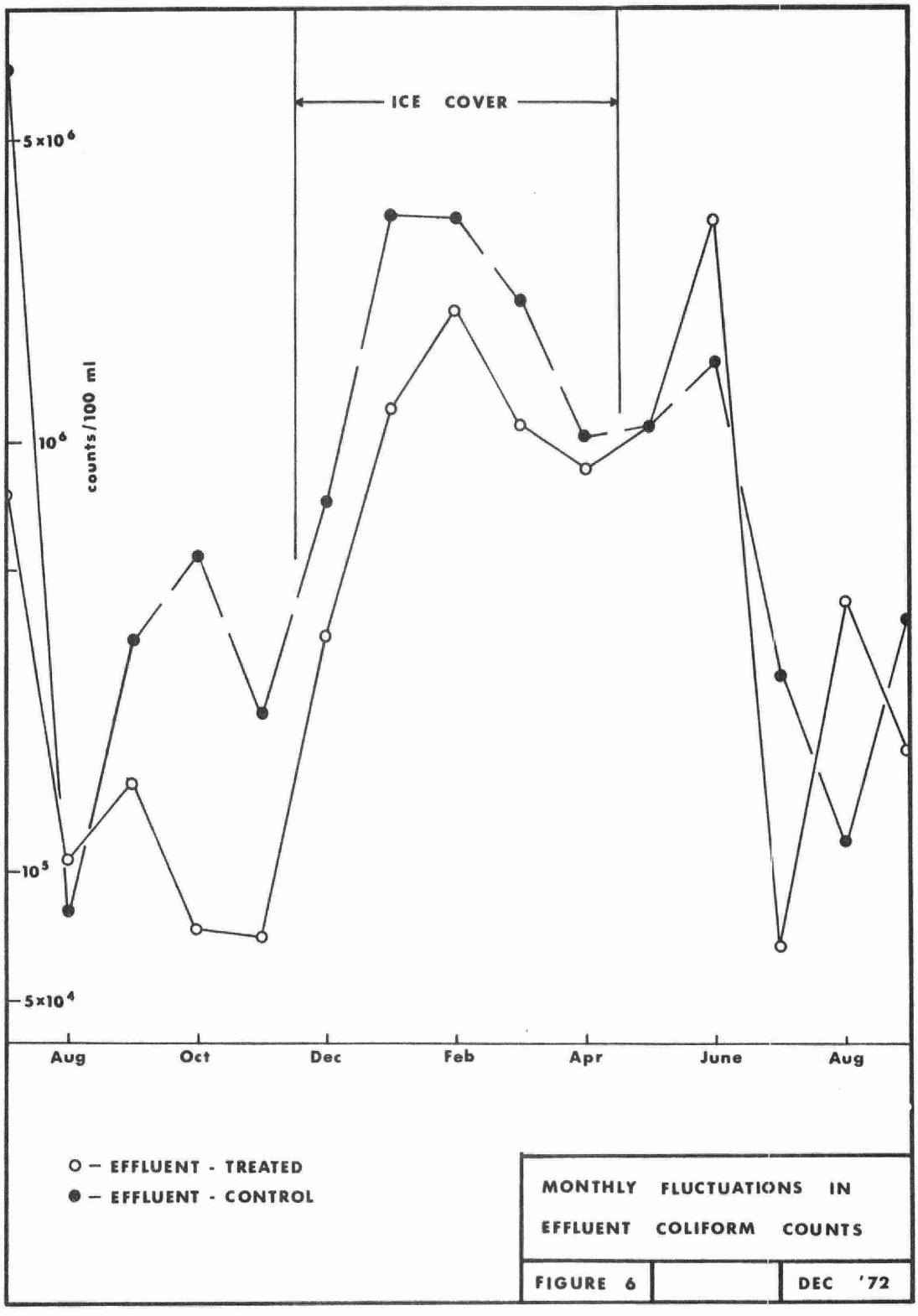
The results obtained from this study substantiate the above. During the winter (71/72), alkalinity levels in the control effluent reached a peak in February exceeding the average influent concentration (387 mg/l) while the treated effluent followed the same trend but at lower concentration (Appendix II). The latter condition is probably due to the ability of alum to reduce alkalinity. The pH levels in both effluents were lowered, approaching 7.0 during this period. Alkalinity levels in both cells dropped rapidly, as the temperature and solar radiation increased, to a minimum in May after complete ice removal allowed intense biological activity. During the summer months, the alkalinity in both effluents levelled off between 240 and 300 mg/l, the treated effluent being higher on the average, indicating that the algae concentration had a more significant effect on alkalinity than did alum. The pH levels were correspondingly lower in the treated cell.

5.5 Bacteria and Algae

Coliform bacteria levels followed a trend similar to that of the alkalinity, with maximum values obtained during the winter (ice-covered) months (Fig. 6). There appeared to be a lag period between breakup (mid-April) and July before the bacteria count reduced significantly which would be a result of slow recovery of predators (rotifers, etc.).

Chlorophyll a counts in the effluents from the control and treated cells were used to assess the effect of influent alum injection on the production of photosynthetic microorganisms. The chlorophyll levels in the treated cell were approximately 50 percent lower than in the control. High chlorophyll in the control effluent was accompanied by higher suspended solids and pH and lower alkalinities relative to the treated effluent.

In the summer of 1971 a profuse growth of the blue-green algae Microcystis was observed in the treated cell. Attempts to remove a scum, formed by these algae, by pumping it onto the berm met with limited success. Heavy rainfall during August dispersed the scum and contributed to a high suspended solid and organic nitrogen content in the effluent. Microscopic examination of the algae in both effluents during the summer of 1972 showed that, of the predominant species, 47 percent were greens, 38 percent bluegreens and 15 percent flagellates. The predominant greens were Chlorella, blue-greens were Chroococcus. The Microcystis bloom did not recur in 1972; a similar blue-green bloom in the untreated Wingham lagoon indicated that this is a natural occurrence not attributable to the alum injection.



MONTHLY FLUCTUATIONS IN EFFLUENT COLIFORM COUNTS

FIGURE 6 | | DEC '72

5.6 Flows and Sludge Buildup

The monthly total inflows to both cells are tabulated in Appendix III. Average flowrate for the study period was 0.184 MIGD (837 m^3/day).

The influent to the east cell was calculated in centimeters to be consistent with precipitation and evapotranspiration values. The exfiltration rate (influent + precipitation - effluent - evaporation) for the period July 1, 1971 to October 31, 1971 was 29.1 cm/year. Flow values to the east cell during 1972 could only be approximated and an exact exfiltration rate was not determined.

An estimation of the sludge buildup in the treated cell due to alum injection was made in May, 1972 using a sludge depth probe. Since the control cell had been drained and scraped in the Spring of 1971 and the equivalent operation performed on the treated cell in the Spring of 1970 (one year prior to the start of treatment), the difference in sludge volumes around the influent pipes should be equal to the volume of the chemically treated sludge. From the sludge profiles the sludge buildup was determined to be 0.4 in/ac/year (2.5 cm/ha/year) and 0.1 in/ac/year in the treated and control cells respectively.

6. SUMMARY AND CONCLUSIONS

As predicted from jar test studies, 80 percent of the influent phosphorus was retained in the east cell of the Shelburne WSP by injecting alum at a concentration of 170 mg/l (Al:P = 1.05:1) into the raw sewage influent. Phosphorus release from the bottom sediments was not apparent during the winter (ice-cover) months in the treated cell.

Average BOD and SS levels in the effluent from the treated cell were slightly lower than those from the control. Free ammonia, alkalinity, pH and chlorophyll measurements in the effluents indicated a reduced algae population in the treated cell relative to the control. Algae types in both cells were the same.

It may be concluded that injection of alum directly into the raw sewage influent to a continuous discharge waste stabilization pond is a viable method for reducing the phosphorus concentration in the effluent.

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APPENDIX I

SHELBURNE WSP : PHOSPHORUS MASS BALANCE AND BOD LOADING

Month	Influent Phosphorus (kg) Treated	Control	Effluent Phosphorus (kg) Treated	Control	BOD Loading (kg/ha/day)
July	145	176	31	46	34.5
August	111	127	21	24	28.9
September	127	124	23	38	17.8
October	90	171	23	82	19.9
November	116	136	25	55	18.4
December	271	271	44	121 *	43.2
January	195	195	25	84	33.2
February	145	145	33	80	24.0
March	94	94	29	85	17.0
April	122	122	48	107 *	23.7
May	162	162	25	81	20.7
June	103	103	43	48	17.4
July	135	135	24	53	24.4
August	314	314	27	58	40.7
September	78	78	23	36	18.3
Total	2208	2353	444	998	Avg= 25.5
Percent Phosphorus Removal			79.9	57.6	

* occurred during high flows due to runoff.

APPENDIX II

SHELBURNE WSP : CHEMICAL ANALYSES *

RAW SEWAGE

	P_t	P_s	BOD	SS	NH_3	Kjel	Hds	AIk	pH
$\bar{X}$	12.2	7.0	175	291	19.3	37	339	387	7.4
X_u	13.6	7.9	200	372	20.1	49	359	434	7.5
X_L	10.8	6.0	151	209	17.6	25	319	341	7.2

Note: $\bar{X}$ is the mean for 60 samples.
X_u and X_L are the Upper and Lower Limits for a 95 percent confidence test.

EFFLUENTS

Month	P_s		SS		Org.N		Alk		pH	
	T	C	T	C	T	C	T	C	T	C
July	1.5	2.3	60	73	8.0	6.9			8.4	8.6
Aug.	1.6	1.6	145	68	10.4	7.0			8.6	8.4
Sept.	2.3	3.9	45	63	7.1	8.2			8.1	8.1
Oct.	1.4	3.6	41	41	5.3	3.9			8.1	8.0
Nov.	1.3	3.2	73	57	5.3	5.4	289	293	8.0	7.8
Dec.	1.0	4.6	35	31	6.9	5.1	283	311	7.7	7.5
Jan.	1.5	6.1	31	38	3.3	5.5	316	345	7.2	7.5
Feb.	2.7	7.4	23	27	4.5	5.2	389	443	7.3	7.3
Mar.	1.6	6.4	14	28	6.0	6.0	327	396	7.2	7.3
Apr.	1.4	4.0	20	25	3.5	4.0	272	302	7.2	7.4
May	0.8	3.1	47	63	5.2	6.9	232	246	8.4	8.4
June	1.3	1.7	50	58	10.3	8.3	281	246	7.7	8.8
July	1.3	1.9	50	82	8.9	7.8	287	257	7.7	8.4
Aug.	1.0	1.3	70	80	8.4	9.8	290	229	8.2	8.8
Sept.	1.0	1.6	63	90	7.8	8.8	266	281	8.6	8.5
Avg.	1.4	3.5	51	55	6.7	6.6	290	304	7.9	8.1

Note: T is the monthly average in the effluent from the alum treated cell; C is from the control.

* All values in milligrams per litre except pH.

APPENDIX III

SHELBURNE WSP : FLOW DATA (INCLUDING PRECIPITATION, EVAPOTRANSPIRATION)

Month	Total Inflow ($m^3 \times 10^3$)	East Influent (cm)	Precipitation (cm)	East Effluent (cm)	Evapotranspiration (cm)	Exfiltration (cm)
July	21.1	40.9	8.7	34.5	14.7	0.4
August	17.6	37.2	9.8	29.9	12.9	4.2
September	15.4	29.3	2.2	22.1	6.8	2.6
October	23.5	30.6	3.8	27.2	4.6	2.6
November	24.5					
December	43.4					
January	24.1					
February	18.7					
March	21.6					
April	44.8					
May	25.4					
June	23.8					
July	27.3	51.2	4.4	40.9	13.9	0.8
August	30.3	56.9	5.9	46.5	10.7	5.6
September	21.3	40.1	5.4	38.9		

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